OPERATING INSTRUCTIONS

for

TYPE 1651-A
BOLOMETER BRIDGE

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

U. S. A.

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for

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BOLOMETER BRIDGE

Form 736-C
May, 1955

GENERAL RADIO COMPANY

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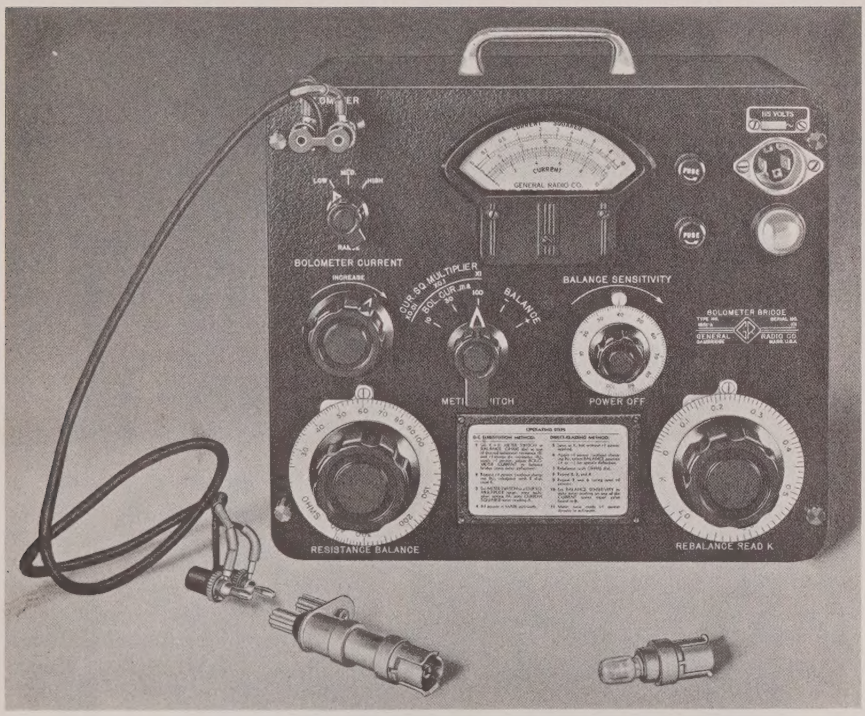


Panel View of the Type 1651-A Bolometer Bridge

SPECIFICATIONS

Range and Accuracy — Substitution Method

With Type 874-H25 Thermistor Unit

Thermistor resistance set for max. sensitivity	0 to	6 mw	±(10% + 0.05 mw)
Thermistor resistance set at 50 ohms	0 to	18 mw	±(10% + 0.12 mw)

With Type 874-H100 Thermistor Unit

Thermistor resistance set for max. sensitivity	0 to	20 mw	±(10% + 0.15 mw)
Thermistor resistance set at 50 ohms	0 to	70 mw	±(10% + 0.5 mw)

With Type 874-HF Fuse Bolometer Holder, MJR 1/32-ampere fuse

Fuse resistance set for max. sensitivity	0 to	8 mw	±(10% + 0.1 mw)
Fuse resistance set at 50 ohms	0 to	14 mw	±(10% + 0.15 mw)
Fuse resistance set for max. power range	0 to	50 mw	±(10% + 0.3 mw)

With Type 874-HF Fuse Bolometer Holder, MJR 1/16-ampere fuse

Fuse resistance set for max. sensitivity	0 to	20 mw	±(10% + 0.5 mw)
Fuse resistance set at 50 ohms	0 to	100 mw	±(10% + 0.75 mw)
Fuse resistance set for max. power range	0 to	500 mw	±(10% + 3 mw)

Bolometer Resistance Range: 25 to 400 ohms.

Current Range: 0 to 100 milliamperes.

Power Supply: 105–125 volts, 60 cycles.

Frequency Range: Determination of power is independent of frequency. Practical range:

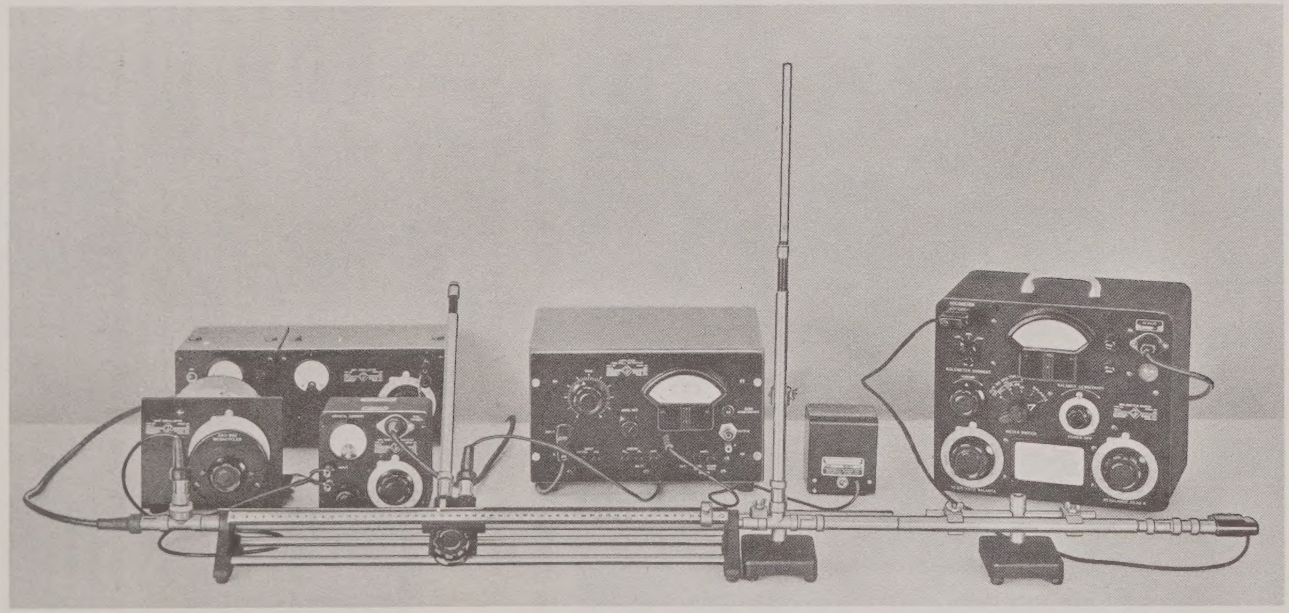
5 — 4000 Mc with thermistor units.
5 — 1000 Mc with fuse units.

Accessories Supplied: One CAP-35 Power Cord; one Type 274-NEO Patch Cord; spare fuses.

Accessories Required: Bolometer element. Types 874-H25 and 874-H100 Thermistor Units, and Type 874-HF Fuse Bolometer Holder are recommended.

Dimensions: (Height) 12 x (width) 12 x (depth) 8¾ inches, over-all.

Net Weight: 22¼ pounds.



View of the Type 1651-A Bolometer Bridge with the associated equipment shown in the diagram of Figure 6, page 11.

OPERATING INSTRUCTIONS

for

TYPE 1651-A BOLOMETER BRIDGE

SECTION 1.0 DESCRIPTION

1.1 GENERAL DESCRIPTION

The Type 1651-A Bolometer Bridge is a general-purpose instrument for use with bolometer elements such as the Type 874-HF Bolometer Fuse Holder, Type 874-H25 Thermistor Unit, or the Type 874-H100 Thermistor Unit for the measurement of r-f power in the milliwatt range. In the measurement the r-f power is dissipated in a bolometer, which is a resistance element with a large temperature coefficient of resistance. The magnitude of the r-f power can be determined either from the difference in d-c bias power required to make the bolometer have the same resistance with and without the r-f power applied, or from the measured change in the bolometer resistance.

In the first method, called the substitution method, the change in d-c bias power is equal to the r-f power. In the second method, a direct-reading method, the meter on the bridge, whose deflection is approximately proportional to the change in the power being dissipated in the bolometer, is calibrated at one level using the substitution method, after which other power levels can be read directly from the meter. Since the direct-reading method requires calibration by the substitution method, the accuracy of the direct-reading measurement is somewhat poorer than the accuracy of substitution measurements.

1.2 CIRCUIT

The heart of the Type 1651-A Bolometer Bridge is the Wheatstone Bridge of Figure 1, in which the bolometer element forms one arm. To measure power with this circuit by the substitution method, the bridge is first balanced with the r-f power applied to the bolometer element. The balance is obtained by adjusting the applied d-c voltage until the bolometer element is heated to a temperature at which its resistance is the value required for a balance. At balance, the total power, P_1, dissipated in the bolometer element is

$$P_1 = I_1^2 R_B + P_{r\text{-}f} \qquad (1)$$

where I_1 is the d-c current flowing through the bolometer at balance, and P_{r-f} is the r-f power being dissipated in the element.

The r-f power is then removed and the bridge rebalanced by increasing the applied d-c voltage, V. The total power dissipated in the bolometer after this balance is

$$P_2 = I_2^2 R_B \qquad (2)$$

Since the same bolometer resistance is required for both balances, the total power dissipated in the bolometer must be the same, therefore

$$P_1 = P_2 \qquad (3)$$

Consequently the r-f power is equal to the difference in d-c power between the final and initial balances, or

$$P_{r-f} = I_2^2 R_B - I_1^2 R_B = I_2^2 R_B \left[1 - \left(\frac{I_1}{I_2}\right)^2\right] \qquad (4)$$

With this basic circuit the r-f power can be determined from a knowledge of the d-c current flowing through the bolometer during the initial and final balances and the bolometer resistance at balance.

In order to simplify the measurement and make the bridge more flexible, the actual circuit used in the Type 1651-A Bolometer Bridge is the modified circuit shown in Figure 2. Here the bolometer resistance required for balance can be varied over an appreciable range by means of the potentiometer that replaces the fixed resistors R_c and R_d in the simple circuit. The potentiometer is calibrated in terms of the bolometer resistance required for balance, and the bridge is thus adaptable to use with bolometer elements having widely varying characteristics. The supply voltage for the initial balance is fixed at V_o, V_k being set to zero, and the initial current adjustment is made by means of the

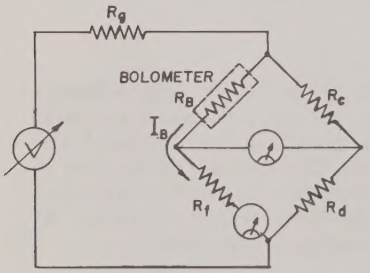


Figure 1. Basic Bridge Circuit for Power Measurement

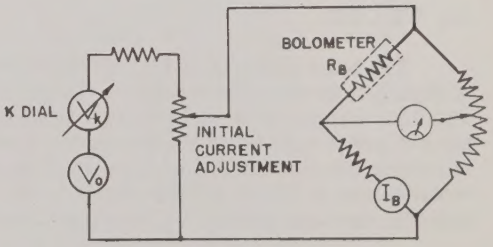


Figure 2. Modified Basic Circuit

potentiometer indicated. The final balance is made by means of V_k. Since the total circuit resistance is the same for the initial and final balances, the ratio of the initial and final bolometer currents is

$$\frac{I_1}{I_2} = \frac{V_o}{V_o + V_k} \tag{5}$$

independent of the setting of the initial-current-adjustment potentiometer. Also, since the supply voltage, V_o, is a constant, Equation (5) shows that the V_k control can be calibrated in terms of $1 - \left(\frac{I_1}{I_2}\right)^2$, which is called the K factor, and, from Equation (4),

$$P_{r-f} = K I_2^2 R_B \tag{6}$$

The voltage control, V_k, is a Variac connected ahead of the rectifier that supplies the bridge with d-c, as shown in Figure 3. The Variac dial is calibrated in terms of the factor K. A voltage stabilizer is used ahead of the Variac to minimize the effects of line voltage variations.

The 200 microampere meter used to measure the degree of bridge unbalance is also used to measure the bolometer current. In order to minimize the effects of the temperature coefficient of the meter winding on the accuracy of the current measurement, a large resistor is connected in series with the meter, and the current is measured by measuring the voltage drop across taps on the fixed resistance arm of the bridge. The taps are arranged to give current ranges of 0 - 10 ma, 0 - 31.6 ma, and 0 - 100 ma. In order to permit direct accurate measurements of I_2^2 over a wide current range, the meter is provided with a current-squared scale which is applicable to all current ranges.

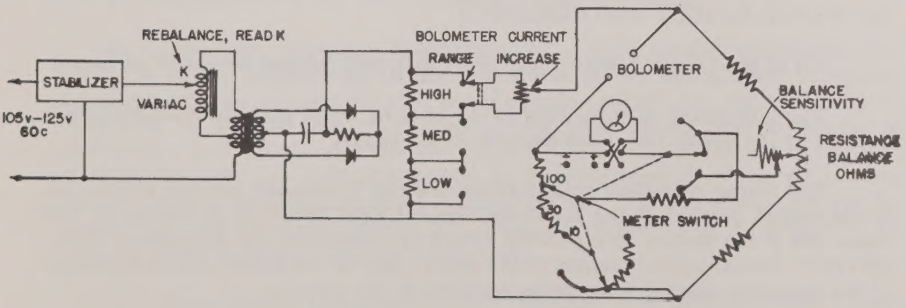


Figure 3. Schematic of Complete Circuit Used in Type 1651-A Bolometer Bridge

The true value of I_2^2 is obtained by multiplying the scale reading by the decimal multiplier indicated by the meter range switch. The current-squared scale is labeled A and the multiplier M; therefore, $I_2^2 = MA$ and the magnitude of the r-f power is

$$P_{r\text{-}f} = \text{MARK milliwatts} \qquad (7)$$

In this type of bridge all quantities are measured after the final balance has been made and after the r-f power has been removed, which eliminates errors due to changes in the r-f power level while readings are being taken and, by permitting the dial and meter measurements to be made slowly and carefully, tends to improve the accuracy of these readings.

The circuit is also adaptable to direct-reading measurements of r-f power, but with somewhat less accuracy than is obtainable using the substitution method. It is convenient to use when a large number of measurements are to be made at power levels not too greatly different from one another. The direct-reading method depends upon the variation in resistance of the bolometer element with r-f power causing an unbalance indication on the meter. The meter indication is closely proportional to the r-f power from zero up to a power level which depends on the type of bolometer element used and the initial bolometer resistance setting. In general, the linear range extends up to power levels of from 10 to 100 milliwatts with less than 10% deviation from linearity. In the direct-reading method, the meter sensitivity is adjusted to read directly in milliwatts after calibration by the substitution method. The initial calibration procedure is more complicated than a single measurement by the substitution method, and in some cases the change in bolometer resistance with r-f power level may have an appreciable effect on the r-f impedance match.

The bridge is adaptable to a large variety of bolometer elements for both direct and substitution measurements. Bolometer resistances between 25 and 400 ohms and bolometer currents up to 100 ma can be accommodated.

1.3 PANEL LAYOUT AND CONTROLS

All of the bridge controls and terminals are located on the front panel.

The bolometer is connected to the binding posts marked BOLOMETER located at the upper left-hand section of the panel.

The meter indicating bridge unbalance and bolometer current is located in the center portion of the panel and the METER SWITCH is visible at the lower left of the meter. The POWER switch is mounted on the BALANCE SENSITIVITY potentiometer located at the lower right of the meter and is actuated at the extreme counter-clockwise position of the control.

The potentiometer controlling the initial current, labeled BOLOMETER CURRENT, is located in the left-center portion of the panel and a range switch for various current levels is located just above it.

The RESISTANCE BALANCE dial is located in the lower-left section of the panel and is calibrated from 25 to 400 ohms.

The K dial is located in the lower-right section of the panel and is calibrated from 0 to 0.7.

Condensed operating instructions are mounted in the lower-center section of the panel.

1.4 ACCESSORIES SUPPLIED

A Type 274-NE Shielded Connector is supplied to make the connection between the bolometer bridge terminals and the bolometer holder. A power cord is also supplied.

SECTION 2.0 OPERATION

2.1 POWER SUPPLY REQUIREMENTS

The Type 1651-A Bolometer Bridge is designed to operate from a-c power sources of the frequency and voltage indicated on the nameplate located above the power input receptacle on the panel. Since the bridge has an internal regulating transformer, no external regulator is required. In fact, the use of an external regulator which appreciably distorts the waveform of the supply voltage may cause errors in the measurements. Large distortions of the waveform due to other sources can also be serious and must be avoided.

The type of circuit and regulator used limits the supply voltage and frequency to the values indicated on the instrument. Models are available for use at other frequencies and voltages, but are not convertible from one to another.

2.2 MEASUREMENTS BY THE SUBSTITUTION METHOD

2.21 Bolometer Element Requirements: As previously mentioned, the bolometer bridge is adaptable for use with a wide variety of bolometer elements. Requirements for an element are that it should operate at a resistance level of between 25 and 400 ohms, a current of less than 100 ma, and be capable of passing d-c current through it. The Type 874-HF Fuse Bolometer Units and the Type 874-H25 and H100 Thermistor Units were specially designed for use with the bridge and are convenient elements to use. The bolometer element is connected to the terminals labeled BOLOMETER on the bridge by means of the Type 274-NE Shielded Connector supplied.

2.22 Effect of D-C Resistance of R-F Source: The bridge balances when the total d-c resistance seen across the BOLOMETER terminals is equal to that at which the bridge is set. Therefore, any d-c resistance effectively appearing in series with the bolometer element must be added to the desired bolometer resistance in order to obtain the setting of the RESISTANCE dial

on the bridge. Also, in calculating the power from the bridge readings, the actual bolometer resistance and not the total effective resistance indicated by the RESISTANCE dial must be used. (See Paragraph 1.2.)

When a Type 874-HF, H25, or H100 Bolometer Element is used, the r-f circuit to which the holder is connected must have a d-c path between the inner and outer conductors with an impedance of less than a few hundred ohms, as there is no internal return circuit provided in the holders for the d-c bolometer current. Best results are obtained when the d-c resistance is negligibly small. If the d-c resistance is not negligibly small, its value must be accurately determined.

The source resistance can be accurately measured using the bolometer bridge by removing the bolometer holder and connecting the BOLOMETER terminals on the bridge to the inner and outer conductors of the coaxial line from the r-f power source. The bridge is balanced using the RESISTANCE BALANCE dial, the reading of which is the source resistance. If the resistance is less than 25 ohms, a series resistor must be used to bring the resistance within the range of the bridge.

If the bolometer bridge is used with a bolometer or thermistor mount containing two bolometer elements which are in parallel across the end of the line for the r-f circuit and which appear in series in the bridge circuit, the r-f input circuit should not have a d-c return unless a d-c blocking capacitor is provided in the mount. An external Type 874-K Series Capacitor can be used if none is provided internally and the r-f source has a d-c through connection. A d-c return in the r-f circuit without a blocking capacitor will short-circuit one of the bolometer elements.

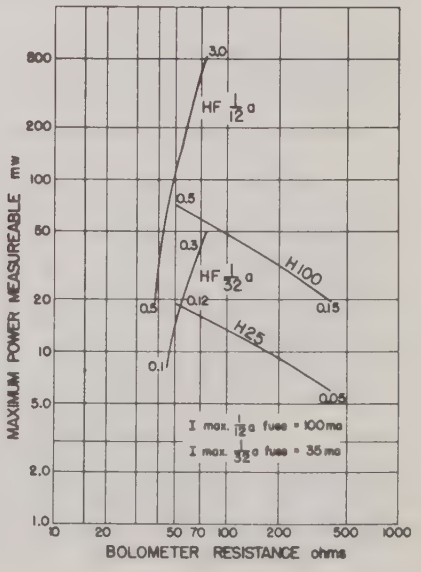


Figure 4. Power-measurement ranges of fuse and thermistor bolometers and the bolometer bridge, by the substitution method, as a function of bolometer resistance. Minimum detectable power in milliwatts is indicated by the numbers at the ends of each curve.

2.23 Choice of Bolometer Element and Operating Point: The power ranges of the bolometer and thermistor units mentioned above overlap one another. The thermistor units have a lower standing-wave ratio, are more rugged and will measure somewhat lower powers than will the fuse elements. The fuse elements, however, are cheap and will measure higher powers than will the thermistor units. The fuse elements are limited in their frequency range by errors caused by standing waves on the fuse wire and in many cases by losses in the transformer used to match them to the r-f power source. Above about 1000 Mc these errors become appreciable.

Figure 4 is a graph showing the power-measurement ranges of the various elements.[1] The curves indicate the maximum power measurable as a function of the bolometer resistance. The small numbers located along the curves are the resolving power of the bridge in milliwatts at the indicated resistance level. From the resolving power figures, the smallest power measurable to any given degree of accuracy can easily be determined as the accuracy is $\pm$(10% + resolving power). Figure 5 is a curve showing the standing-wave ratio produced in a 50-ohm transmission line terminated in a bolometer element whose d-c resistance is set at 50 ohms. The most satisfactory element and operating point for the measurement of any power within the range of the elements can also be determined from the curves. As can be seen, the thermistor units are capable of measuring the largest powers when the resistance level is 50 ohms, and are the most sensitive at 400 ohms. The fuse bolometer units[2] have the greatest power-handling capacity at resistances above 50 ohms. The maximum power level is determined by the maximum current an element can handle. The maximum allowable currents for the fuses are 20% greater than the rated current, namely 35 ma and 100 ma respectively for the 1/32 and 1/12 ampere units, as the fuses are rated very conservatively. The maximum currents for the Type 874-H25 and H100 Thermistor Units are 25 and 50 milliamperes respectively.

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[1] The characteristics of the fuses are subject to a considerable variation between different units. The thermistors, however, are quite uniform.

[2] Other fuses may be substituted for the types supplied with the fuse bolometer holder to obtain different characteristics. The Type 874-HF Bolometer Fuse Holder is designed for 1/4 x 1 inch fuses such as the AGX or 8AG Fuses.

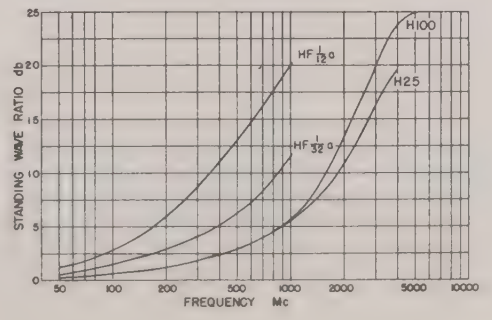

Figure 5. Standing-wave ratio as a function of frequency of the fuse bolometer and thermistor units.

In the general case, the maximum measurable r-f power is 0.7 of the d-c power dissipated in the bolometer at balance with no r-f power applied. The amount of d-c power dissipated in an element can be varied by changing the resistance level. The resolving power of the bridge decreases as the d-c power increases, hence it usually is desirable to keep the d-c power small when measuring small amounts of r-f power. In many cases, however, best results are obtained with a 50-ohm resistance level as it is most easily matched to a 50-ohm transmission line.

2.24 Checks to Prevent Overloading the Bolometer: In general, bolometer elements can be damaged by the dissipation of power in them beyond their ratings. It is, therefore, important in using these elements to prevent overloads. This can be done in the following manner:

(1) Before turning the a-c power switch on, set the BOLOMETER CURRENT control to its extreme counter-clockwise position, the current range switch to LOW, and the K dial to zero.

(2) Then set the RESISTANCE BALANCE dial to the desired resistance level and turn on the a-c power.

(3) Gradually increase the current by means of the BOLOMETER CURRENT control and the current RANGE switch and observe the magnitude of the bolometer current and degree of unbalance by switching the meter back and forth from a suitable current range to an unbalance indication of the proper polarity. Note the polarity which gives an upscale meter reading with low power. Increase the current[3] until the bridge is balanced or the maximum current rating of the bolometer element is reached. If the current rating is reached before the bridge is balanced, set the RESISTANCE BALANCE dial to a new resistance value and repeat the procedure.

The chart in Figure 4 can be used as a guide to determine the resistance ranges obtainable within the power ratings of the Type 874 bolometer elements. Small deviations from the average characteristic plotted are found in various units. With the fuse elements, which have a positive coefficient of resistance, the meter will read upscale with the switch in the (-) position as long as the power is less than that required for balance. With the thermistor elements, which have a negative coefficient of resistance, the meter will read upscale with the switch in the (+) position as long as the power is less than that required for balance.

2.25 Measurement of R-F Power:

(1) After the bridge has been set up as previously outlined and the meter-switch set to indicate unbalance of the same polarity as found for an upscale

[3]As the current is increased from zero, the meter indication unbalance will travel upscale from zero, reach a maximum, return to zero at balance, and then tend to increase in a negative direction. The zero meter indication at zero current should not be confused with a balance indication.

reading for low powers in Step 3 in Paragraph 2.24, reduce the d-c power to zero (RANGE switch at LOW and BOLOMETER CURRENT control in extreme counter-clockwise position) and apply the r-f power. It probably will be necessary to reduce the sensitivity of the meter with the control provided when the bridge is far off-balance to keep the meter on-scale. If the magnitude of the r-f power is less than the d-c power required to balance the bridge in Step 3 in Paragraph 2.24, the meter will read upscale; if the power is greater, the meter will read below zero. If the meter reads below zero, the measurement of the power cannot be made with the existing bridge settings,[4] and the input power to the bridge required for balance as measured in Step 3 in Paragraph 2.24 must be increased by changing the resistance level or the bolometer element.

(2) Assuming that the meter reads upscale, increase the d-c bolometer current[5] using the controls provided until the meter indicates that a balance is reached.

(3) Then remove the r-f power without changing the value of d-c resistance of the r-f source, R_S, seen in series with the bolometer element by the bridge, and rebalance the bridge using the K dial.

(4) Switch the meter to read BOLometer CURrent, and note the reading, A, of the CURRENT SQUARED scale and the CURrent SQuared MULTIPLIER, M, used.

(5) The r-f power is then:

$$P = \text{MARK milliwatts}$$

where R is the resistance of the bolometer element. If there is no d-c resistance in series with the bolometer element as seen by the bridge, R is the reading of the RESISTANCE BALANCE dial. If there is such a series resistance, R_S, it must be subtracted from the resistance indicated on the RESISTANCE BALANCE dial.

2.26 Matching Bolometer to a 50-Ohm Line or Source:

2.261 Matching Bolometer to a 50-Ohm Line: As shown in Figure 5, the VSWR (voltage-standing-wave ratio) of the Type 874 Bolometer Elements with the d-c resistance set at 50 ohms increases as the frequency increases. At the higher frequencies, if power into a 50-ohm load is desired, a matching transformer must be used to transform the actual impedance of the bolometer to 50 ohms. Figure 6 shows one type of transformer which can be made up of

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[4]Since the K dial is calibrated only to 0.7 of the d-c power, an r-f power input of from 0.7 to 1.0 of the original d-c power will produce an upscale meter reading, but it will not be possible to measure the r-f power. Under these conditions the resistance level of the bolometer element should be changed or a different bolometer element used.

[5]See Footnote 3.

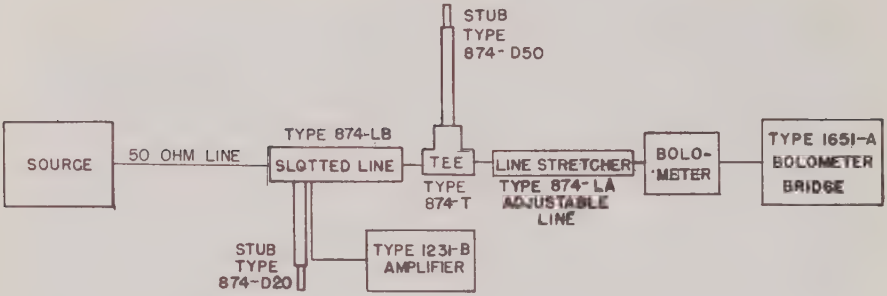

Figure 6. Block diagram of a transformer made up of standard Type 874 Coaxial Elements for matching a bolometer element to a 50-ohm line.

standard Type 874 Coaxial Elements. A Type 874-LB Slotted Line is used to measure the VSWR and hence indicate when the desired impedance is obtained. It is sometimes desirable to adjust the d-c bias power in the bolometer as the matching transformer is adjusted to keep the d-c bolometer resistance at 50 ohms.

In matching a load to a line, it is sometimes difficult to make the preliminary adjustments of the transformer elements necessary to reduce the VSWR to a moderate value. One method of making the adjustments which usually simplifies the procedure is the following:

(1) Find the minimum voltage point on the slotted line and increase the detector sensitivity until the meter deflection at this point is an appreciable fraction of full scale.

(2) Adjust one of the transformer elements while following the minimum voltage point with the probe on the slotted line until the meter deflection is maximized.

(3) Repeat the procedure while adjusting the other transformer element.

(4) Continue the process alternating between the two adjustable elements until a reasonably low VSWR is obtained. Make the final adjustments to reduce the VSWR to unity by actually measuring the minimum and maximum voltages on the line and minimizing their ratio.

2.262 Matching the Bolometer to a Source Having an Arbitrary Output Impedance: The same type of matching transformer as indicated in Paragraph 2.261 can be used in this case; however, no slotted line is required. The bolometer bridge is initially balanced with no r-f power applied. The r-f power is then applied and the transformer adjusted for the maximum unbalance indication on the meter. If the sum of the d-c and r-f power is liable to be in excess of the rating of the element, the bridge should be rebalanced occasionally during the matching using the resistance dial. The bolometer resistance

corresponding to the maximum power rating can be determined by measuring the resistance with rated current passing through the bolometer with no r-f power applied. After the indication has been maximized by adjustment of the transformer, balance the bridge using the RESISTANCE BALANCE dial and measure the r-f power by following Steps 3, 4, and 5 of Paragraph 2.25.

2.27 Accuracy: The accuracy with which the bolometer bridge can measure the change in power dissipated in a bolometer element is controlled by the accuracy of the determination of the various factors involved in the calculation of the power.

The accuracy of the meter is the most important factor, because the square of the current is used in the calculations, which means the error in power determination is twice the meter error. The accuracy of the meter on the linear scales is $\pm$(1-1/2% of the reading + 1/2% of full scale). At full scale this means the meter may contribute as much as $\pm$4% error in the power measured. At one-third of full scale the maximum possible error due to the meter may be as great as $\pm$6%. A range switch is provided to keep the meter readings above 1/3 of full scale for currents above 3 milliamperes.

The K dial calibration is accurate to $\pm$(1% of the reading + .005) and the bolometer resistance can be determined with an accuracy of better than $\pm$1%. The overall accuracy obtainable in a particular measurement depends on the magnitude of the bolometer current and the magnitude of the K dial reading. However, accuracies of better than $\pm$10% can easily be obtained using the substitution method if the measured power is not too small.

2.3 MEASUREMENTS BY THE DIRECT-READING METHOD

2.31 General Description: When the bolometer bridge is used for direct-reading measurements, the r-f power is proportional to the meter deflection and is read on one of the linear current scales. The proportionality factor is determined by a measurement by the substitution method and can be set to unity or a power of ten by adjusting the meter sensitivity, thus making one of the linear meter scales direct-reading in milliwatts. Measurements by the direct-reading method are not as accurate as by the substitution method, as the meter is calibrated by the substitution method, and the meter reading is not accurately a linear function of the r-f power. Also, from the principle of operation it is evident that the resistance of the bolometer, and hence its r-f impedance, must change as the power level is changed. When the power for full-scale deflection is large, the resistance change may be appreciable and in some applications will necessitate the readjustment of matching transformers to obtain the desired impedance match between the bolometer and the r-f circuit. However, in some applications in which accuracies of 20% or so are adequate, the direct-reading method is more convenient than the substitution method. (10% accuracy in substitution method, 10% deviation from linearity.) Of course if more accurate results are desired, it is possible to check and correct for the nonlinearity by calibration at two or three power levels using the substitution method.

2.32 Bolometer Element Characteristics: The sensitivity and deviation of the power scale from linearity is a function of the initial resistance setting of the bolometer and the magnitude of the power required for full-scale meter deflection as well as of the type of bolometer element used. Figure 7 shows a set of curves from which operating characteristics of the H25 and H100 Thermistor Units can be determined. The solid lines represent the r-f power required for full-scale deflection of the meter as a function of bolometer resistance with the BALANCE SENSITIVITY control set for maximum sensitivity. If the minimum power for full-scale meter deflection at the operating resistance level lies below 3.16 milliwatts, the meter sensitivity can be decreased by adjustment of the BALANCE SENSITIVITY control until the deflection for 3.16 milliwatts, or any fraction thereof, agrees with the reading of the 0 - 31.6 linear scale on the meter divided by ten. If the power for full-scale deflection lies between 3.16 and 10 milliwatts, the 0 - 10 scale on the meter can be made direct-reading by adjusting the sensitivity properly. It is not necessary to use a value of r-f power for the calibration exactly equal to the full-scale power, as the meter can be calibrated at any point; for the greatest accuracy, however, the calibration should be made in the upper part of the meter scale.

The meter indication is proportional to the r-f power input for small inputs. As the r-f power input is increased, the deviation from the relationship between r-f power and meter indication gradually becomes greater and greater. The maximum power measurable for a deviation from linearity of less than 10% is indicated by the dotted curves in Figure 7. The meter sensitivity can be reduced to a value which results in full-scale power up to the value indicated by the graph before the deviation exceeds that indicated above. Smaller deviations are obtained at full-scale sensitivity settings corresponding to lower power levels. Since in the direct-reading method the linear relationship is assumed to hold, deviations from linearity are possible sources of error.

Figure 8 shows similar curves for the Type 874-HF Fuse Bolometer Holder with Type MJR 1/12 and 1/32 Ampere Fuses.

2.33 Calibration Procedure: The steps in calibrating the instrument for direct-reading measurements are as follows:

(1) Set the K dial at zero, METER SWITCH at balance, RESISTANCE BALANCE dial at sum of desired bolometer resistance, R,[6] and r-f source d-c resistance, R_S, and BOLOMETER CURRENT range switch and control at minimum power. Then increase BOLOMETER CURRENT until bridge balances[7] (zero deflection).

(2) Apply r-f power (without changing R_S), select BALANCE position (+ or -) for upscale deflection.

(3) Rebalance with the RESISTANCE BALANCE dial.

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[6]See Paragraph 2.22.

[7]The meter will also read zero at zero d-c current through the bolometer element. This, however, is not an indication of balance.

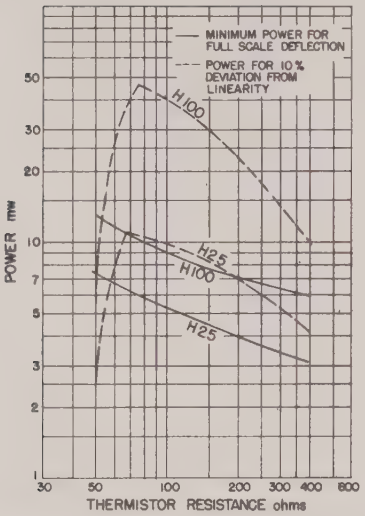

Figure 7. Sensitivity and power-measurement ranges of the thermistor units and bolometer bridge for the direct-reading method.

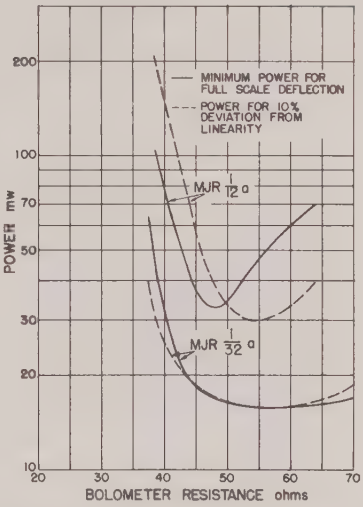

Figure 8. Sensitivity and power-measurement ranges of the fuse bolometer and fuses as indicated for the direct-reading method.

(4) Remove r-f power (without changing R_S), rebalance with K dial, and read K.

(5) Set METER SWITCH to a CURrent SQuared MULTIPLIER range; note multiplier setting M and CURRENT SQUARED meter reading A.

(6) R-F power = MARK milliwatts

(7) Reset the RESISTANCE BALANCE dial to original reading and repeat Steps 1 and 2.

(8) Set BALANCE SENSITIVITY to make meter reading on one of the CURRENT scales equal[8] to the value found in Step 6.

(9) Meter now reads r-f power directly in milliwatts.

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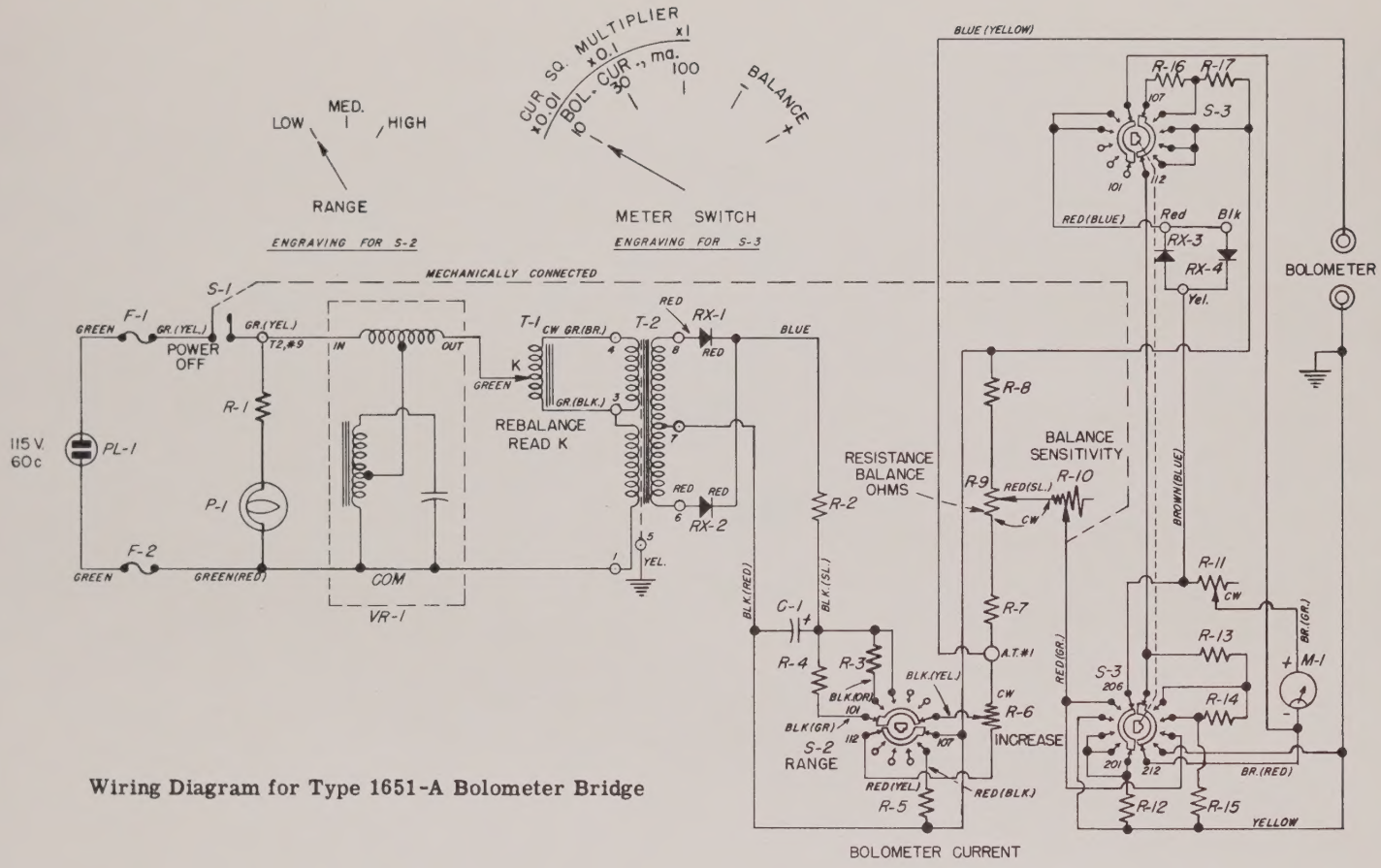
[8]In some cases with fuse elements the sensitivity may be too low to obtain a satisfactory reading with the scale set to read directly. Under these conditions, the sensitivity should be set at maximum; the meter reading noted and divided by the actual power measured in Step 6. All succeeding meter readings should be multiplied by this factor to obtain the true power.

RESISTORS			TYPE
R-1	= 680 Ohms	±10%	REC-41BF
R-2	= 220 Ohms	±15%	REPO-6
R-3	= 510 Ohms	±15%	REPO-7
R-4	= 1.2 K Ohms	± 5%	REPO-7
R-5	= 510 Ohms	± 5%	REPO-3
R-6	= 1 K Ohm	± 5%	371-CT-2
R-7	= 150 Ohms	± 1%	829-481
R-8	= 150 Ohms	± 1%	829-481
R-9	= 500 Ohms	± 5%	214-C
R-10	= 10 K Ohms	±10%	POSC-17
R-11	= 200 Ohms	± 5%	301-404
R-12	= 4.27 k Ohms	± ¼%	510-372
R-13	= 68.79 Ohms	± ¼%	510-338
R-14	= 21.39 Ohms	± ¼%	
R-15	= 9.82 Ohms	± ¼%	
R-16	= 1.80 Ohms	± ¼%	510-339
R-17	= 0.20 Ohms	± 1%	

CONDENSER			
C-1	= 100μf	150 w.v.	COE-45

MISCELLANEOUS		
S-1	= Switch (S.P.S.T.)	Part of R-10
S-2	= Switch	SWRW-19
S-3	= Switch	SWRW-20
P-1	= Pilot Light 120V 6 Watt	2LAP-430
F-1	= Fuse 0.5 amp. 3AG Slow-Blow	(GR FUF-1)
F-2	= Fuse 0.5 amp. 3AG Slow-Blow	(GR FUF-1)
T-1	= Varlac 200B-404	
T-2	= Transformer 485-464	
RX-1	= Rectifier	2RE-3
RX-2	= Rectifier	2RE-3
RX-3, RX-4	= Rectifier	2RE-8
M-1	= Meter 200μa	MEDS-45
VR-1	= Voltage Regulator	4REV-1
PL-1	= Input plug	CDPP-562A



Wiring Diagram for Type 1651-A Bolometer Bridge

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